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***PRETERM INFANTS' RESPONSES TO MUSIC:
AN INTEGRATIVE LITERATURE REVIEW***

Ashley L Hodges, PhD, WHNP-BC
Assistant Professor
School of Nursing
University of Alabama at Birmingham
Birmingham, Alabama

Lynda Law Wilson, RN, PhD, FAAN
Professor and Deputy Director,
WHO/PAHO Collaborating Center on International Nursing
School of Nursing
University of Alabama at Birmingham
Birmingham, Alabama

Abstract

This review presents a systematic integrative summary of research that has been focused on the effects of music, auditory stimulation, or music therapy provided to premature infants in the neonatal intensive care unit (NICU). Studies were included in the review if they met the following criteria: (A) included premature infants (less than 37 weeks gestational age at birth) in the NICU, and (B) evaluated the effects of music on the infant's physiologic or behavioral responses during the infant's stay in the NICU. Studies were identified through a search of Medline and CINAHL databases from 1970 to 2010. The final sample of 35 studies varied in sample size and characteristics, behavioral and physiologic dependent variables, procedures for selection of study participants, design, and methods of data analysis. Areas of consistency and inconsistency in the findings across these studies, and proposed recommendations for future research are identified. Future research should compare the effects of different types of live and recorded music, presented over different frequencies, durations, and decibel levels, and should examine differences in response to the music based on infant characteristics such as gestational age, morbidity level, and behavioral state.

***PRETERM INFANTS' RESPONSES TO MUSIC:
AN INTEGRATIVE LITERATURE REVIEW***

Introduction

The use of music in medicine is not a new concept. In 1914, the *Journal of the American Medical Association* published a report regarding the use of music for patients undergoing regional or local anesthesia.¹ During that time, Duke University hospitals were using music in operating and recovery rooms.² The discipline of medical music therapy began after World War II when community musicians went to Veterans Hospitals around the country to play for the thousands of veterans suffering both physical and emotional trauma. The patients' notable physical and emotional responses to music led the doctors and nurses to request that hospitals hire musicians.³ During the early 1950s, studies showed beneficial effects of music in surgical patients, such as increased cardiac output and decreased heart rate (HR), respiratory rate, and blood pressure (BP).⁴ The study of the effects of music on preterm infants has been championed by the American Music Therapy Association, which was founded in 1998 through the merging of the National Association for Music Therapy (founded in 1950) and the American Association for Music Therapy (founded in 1971).⁵ Music therapy is now widely used in hospitals and other health care facilities throughout the world.

Researchers in the 1970s began evaluating the behavioral responses of preterm infants to stimulation. Katz⁶ was the first to publish findings indicating that premature infants in the neonatal intensive care unit (NICU) benefit from auditory stimulation. During that same time, Segall⁷ reported that postnatal auditory stimulation promoted a cardiac response. When the infant was crying, the HR decreased in response to auditory stimulation; during the quiet state, the infant's HR increased in response to auditory stimulation.⁷ Since the early 1990s researchers began to examine the effects of music on physiologic outcome variables such as HR, BP, oxygen saturation, and respiratory rate.⁸⁻¹⁵ Interest in examining the effects of different types of music as well as those of different modes of delivery, was also evident in reports published beginning in the 1990s.^{11,13,14}

This review presents a summary of research that has been focused on the effects of music, or music therapy provided to premature infants in the NICU. For the purpose of this analysis, music therapy is defined as the clinical and evidence-based use of music interventions to accomplish individualized goals.⁵ Music is defined as "that form of interhuman communication in which humanly organized, non-verbal sound is perceived as vehiculating primarily affective (emotional) and/or gestural (corporeal) patterns of cognition."¹⁶ Auditory stimulation is defined as any sound that activates the auditory system.

Studies were included in this review if they met the following criteria: (A) included premature infants (less than 37-week gestational age at birth) in the NICU and (B) evaluated the effects of music on the infant's physiologic or behavioral responses during the infant's stay in the NICU. Studies were identified through a search of Medline and CINAHL databases from 1970 to 2010, using the search

terms *preterm infant*, *neonate*, *music*, *sensory intervention*, and *stress*. Additional studies were identified by reviewing reference lists and keywords of retrieved studies, including *music therapy*, *preterm infant*, *neonatal intensive care*, *therapeutic intervention*, *singing*, and *music*. The final sample included 35 studies that were published from 1971 through 2010.

These studies were grouped according to the type of music provided and reviewed to answer the following research questions: (1) What were the types and amounts of live and recorded music interventions provided? (2) What were the effects of the different types of music on physiologic variables heart rate [HR], oxygen saturation, and blood pressure [BP]? (3) What were the effects of different types of music on behavioral variables? and (4) Were there differences in effects of music provided during stressful versus non-stressful procedures?

Effects of Recorded Speech and Music on the Preterm Infant

Twenty studies were identified that evaluated the effects of recorded speech and music on the preterm infant. Details of the 20 studies that examined effects of recorded speech and music can be found in Table 1.

Table 1. Summary of Recorded- Speech and Music Studies

Katz⁶ and Segall⁷ were the first to publish findings from studies comparing preterm infants' responses to auditory stimulation provided by a prepared monologue of the mother's voice compared to routine ambient noise. The samples in these studies included 60 and 62 infants, respectively, who were 28 to 32 weeks' gestational age at birth. Each researcher used a two-group experimental design in which one group was a control (routine nursery care) group. Segall reported random assignment of infants to group but no blinding of researchers, and Katz failed to report whether random assignment was used but indicated blinding of researchers. Katz reported an increase in auditory and visual function and in motor and tactile/adaptive maturation. Both Katz and Segall concluded that preterm infants were responsive to auditory stimulation. Segall also reported that preterm infants had different HR responses to auditory stimulation and that these differences depended on behavioral state. When the infant was crying, the HR decreased when the infant was exposed to the mother's voice; when they were not crying, infants exposed to the mother's voice had increased HRs.

The most common type of music used in research involving the preterm infant has been recorded female singing combined with instrumental music. Eighteen studies utilized a variety of types of recorded music.^{8-15 17-26} Of the 18 studies of recorded music, 9 included vocal music,^{9,10,12,13,17,18,21,22,26} 3 included "transitions," or a combination of digital samples of actual womb sounds and barely discernable synthesized female vocal harmonies,^{8,15,18} and 6 included instrumental music only.^{11,14,20,23-25}

The decibel levels of the music provided in 17 of these 18 studies were relatively consistent, and ranged from 60 dB to 80 dB, although one study reported a dB level of only 35. However, the scale of measurement was often not reported. This limitation makes it difficult to compare the effects of the volume of music used. Kaminski and Hall²⁰ reported a set level of 35 dB through use of a speaker pillow placed under the infant. Other researchers reported using speakers placed near the infant's head or using insert and phonopad earphones to deliver the music. Speakers were placed 3 to 20 inches from the infant's head, but many researchers did not report whether the decibel level was measured at the infant's ear.

The number of subjects per study ranged from 4 to 153 infants. Burke, Walsh, Oehler, and Gingras⁸ enrolled 4 infants at post-conceptual ages 25, 28, 31, and 35 weeks. Earlier studies by Chapman¹⁴ and Malloy²⁵ involved 153 and 127 infants, respectively. The remaining studies had sample sizes of 10 to 52 infants, with eight studies having 17 to 30 infants.

Gestational age at birth ranged from 24 weeks to 42 weeks. Kaminski and Hall²⁰ included infants 36 to 42 weeks' gestational age at birth. Lorch, Lorch, Diefendorf, and Earl²³ reported post-conceptual ages ranging from 32 to 36 weeks at enrollment. All other studies included infants 24 to 37 weeks' gestational age at birth. Physiologic outcomes such as HR, mean arterial pressure, oxygen saturation, and/or respiratory rate were examined in several studies evaluating the effects of recorded music.^{8-13 17-19,21,23,26}

Effects of Recorded Music on Oxygen Saturation

Researchers from seven of eight studies that investigated the effects of recorded music on oxygen saturation reported that music resulted in increased oxygen saturation levels.^{7,8,12,15,18,21,26}

Johnston, Filion, and Nyut¹⁹, however, reported a decreased oxygen saturation level after a music intervention. This study included only 20 infants who were 32-36 weeks gestation. All infants were exposed to a recording of their mother talking in a soothing manner for 10 minutes, three times a day for a 48 hour period after feedings. At the end of the 48 hours, the next time the infant required a heel lance, the infant was randomized to one of two conditions: a control condition, or a maternal voice condition. In the maternal voice condition, the recording of the mother's voice was initiated 1 minute prior to the heel lance, and continued until the infant's heart rate and oxygen saturation levels returned to baseline levels.¹⁹ There were no differences in infants' pain responses comparing the two conditions, however the mean oxygen saturation levels were lower in the voice condition during the final phase after the heel lance (94.1 versus 96.2, $p < .01$). Johnston et al. concluded that the volume of the recording (60 to 70 dB) and the placing of the speakers in the isolette may have been aversive to these 20 infants, although this decibel level and placement of speakers was consistent

with other similar studies, and caused the oxygen level to decrease. Although the mean oxygen saturation levels in both conditions were within normal limits, the authors concluded that the findings did not support the hypothesis that maternal voice would have a comforting effect during a painful procedure for preterm infants.

The decibel levels of the music provided in these eight studies were relatively consistent, and ranged from 60 dB to 80 dB. The number of subjects per study ranged from 4 to 66 infants. Gestational age at birth ranged from 24 weeks to 42 weeks. A major limitation of all eight studies was the failure to report blinding of researchers to group assignment. There were wide variations across these eight studies in duration of music. However, all eight studies used recorded female singing. In general, the results suggest that female singing results in increased levels of oxygen saturation.

Effects of Recorded Music on Heart Rate

Five of six studies of the effects of recorded music on HR yielded reports of a decreased HR after exposure to the music intervention.^{8,9,13,17,21} Butt and Kisilevsky⁹ compared responses to two kinds of recorded lullabies (acapella singing versus instrumental piano) that were played for 10 minutes after two separate heel lance procedures. The authors found a significant decrease in HR in the 6 infants who were greater than 31 weeks' post-conceptual age, but not in the 8 infants less than 31 weeks' post-conceptual age. The type of music (instrumental versus voice) did not seem to influence the effect of gestational age, although there were some differences in infants' responses based on type of music. One possible explanation for the difference between the findings for the two gestational age groups is that infants who were less than 31 weeks' post-conceptual age did not show as much stress or pain during the heel lance as the infants more than 31 weeks' post-conceptual age. Butt and Kisilevsky proposed that, because the younger infants' response to the heel lance was not as pronounced, it was possible that those infants could not mount and maintain as much of a stress response; thus any return to baseline was not statistically significant. No difference was found between types of music.

Cassidy¹³ studied the effect of decibel level of music stimulation and gender on head circumference, HR, respiratory rate, and oxygen saturation. Half of the 63 study infants were exposed to 20 min of lullaby music on 2 days followed by 20 min of classical music on 2 days. The other half listened to the same music for the same duration in reverse order. One quarter of the infants listened to the music at 65 dB, one quarter at 70 dB, one quarter at 75 dB, and one quarter received no music stimulation. The author reported a significant decrease in HR regardless of treatment condition (pretreatment mean – 160.69; during treatment mean – 159.44; post-treatment mean – 158.33). There were no other significant effects.

Keith et al.²¹ studied 22 infants who had each experienced at least one episode of inconsolable crying lasting for more than 5 minutes. On two days the infants received a recorded music intervention for 18 minutes, and on two other days, no music was provided. There was a significant decrease in HR from a mean of 152.15 at baseline to a mean of 144.39 after crying episodes with the music intervention, but there were no significant differences in HR noted in the no music condition. Further, Calabro et al.¹¹ used instrumental *Brahms' Lullaby* and found no significant effect on HR.

Coleman et al.¹⁷ and Burke et al.⁸ also reported decreased heart rates following exposure to a speaking and singing music condition, respectively. In contrast, Calabro, Wolfe, and Shoemark¹¹ found no effect on HR of an instrumental music lullaby intervention that was provided on 4 consecutive days to a group of 11 infants.

The decibel levels of the music provided in these six studies were relatively consistent, and ranged from 60 dB to 75 dB, with Keith et al.²¹ reporting only less than 70dB. The number of subjects per study ranged from 4 to 66 infants. Gestational age at birth ranged from 25 weeks to 36 weeks. Duration of music was relatively consistent from 10 to 20 minutes. Five studies used some variation of recorded female singing, and none of the studies reported blinding of researchers to group assignment. In general, the findings suggested that music resulted in decreased HR, particularly in infants greater than 31 weeks gestational age.

Effects of Recorded Music on Blood Pressure

Only two studies reported the effects of recorded music on BP. Lorch et al.²³ (n=10) compared responses of infants during a recorded sedative-music intervention and to stimulating music. The authors reported that in comparison with baseline, levels of systolic BP were higher and more variable during stimulating music than during sedative music; however, sedative music resulted in a more HR variability. Keith et al.²¹ (n=24) compared mean arterial pressure on two music intervention and two no music intervention days. No statistically significant differences were noted for mean arterial pressure. Although length of music (18 and 20 minutes) and gestational ages (32 to 36 weeks and 32 to 40 weeks) were similar in these two studies, further research is needed to compare BP response to different types of music.

Effects of Recorded Music on Behavioral Responses

A total of nine studies reported effects on behavioral responses.^{8-10,17-22} Eight of these studies reported some effect.^{8-10,17,18,20-22} Behavioral outcomes, although reported frequently as significant, were often not specifically defined. The favorable behavioral results most often reported to have occurred during or

immediately after a music intervention were an increase in quiet alert states or quiet sleep states, or a decrease in high arousal time.^{8,17,20,22}

Caine¹⁰ reported an increase in *non-stress behaviors* for infants (n=52) exposed to recorded lullabies. However, the terms *non-stress behaviors* were not defined. Kaminski and Hall²⁰ (n=20) reported a lower amount of time in high arousal states during a 2-hr music intervention than during a 2-hr control period. Butt and Kisilevski⁹ (n=14) found that, after undergoing a heel lance procedure, infants who were more than 31 weeks' post-conceptual age demonstrated a more rapid return to behavioral stability after exposure to recorded music than they showed after exposure to the absence of music. Behavioral stability was defined as a return to baseline measures of HR, oxygen saturation, and behavioral state score. Collins and Kuck¹⁸ (n=17) reported improved behavioral states; the authors defined *behavioral states* as changing from being agitated or fussy to being asleep or awake, although they did not clearly describe the means by which these states were measured.

Keith et al.²¹ (n=24) reported significant differences in duration of crying episodes. On music intervention days the mean duration of crying was 5.53 min compared to no music intervention days when the mean duration of crying was 23.14 min. Johnston et al.¹⁹ (n=20) found no significant differences in behavioral indicators of pain (facial actions and neurobehavioral state as defined in the Premature Infant Pain Profile) when infants were exposed to recorded maternal singing and speech one min before, during, and after heel lance.

Effects of Recorded Music on Other Outcome Variables

Findings from several studies suggested that exposure to recorded music might have beneficial effects on other variables, including length of hospital stay, caloric intake, resting energy expenditure (REE), and weight gain. In Chapman's¹⁴ study 153 infants were randomly assigned to either a control group, a group exposed to tape recordings of their mother's voice, or a group exposed to recordings of a lullaby. Accelerometers were worn unilaterally for a 24 hour period on the ankle and wrist prior to transfer to the alternate side for a further 24 hours. No statistically significant differences were demonstrated among the limb patterns of the infants in the three groups, although there was large intra-group variation in gross activity, with the majority of subjects demonstrating upper limb activity. Malloy²⁵ studied 127 infants who received a recorded instrumental *Brahms' Lullaby*, a recorded maternal speech intervention, or routine care. Infants exposed to the recorded instrumental music were 9.9 days younger at discharge than those in the routine-care group. In comparison with infants in the routine-care group, those exposed to recorded maternal speech were 6.2 days younger at discharge.

A decrease in length of hospital stay was also reported by Caine¹⁰ (n=52). The mean length of hospitalization for infants in the intervention group was 26 days,

whereas that for infants in the routine-care control group was 31 days. Coleman et al.¹⁷ (n=66) also reported that infants who were placed in a routine-care control group had longer hospital stays (38.2 days vs. 35.7 days, respectively) compared to infants who were exposed to recorded sung and instrumental lullabies. An increase in caloric intake was also reported by both Caine and Coleman et al., with increased weight reported as significant by Coleman et al. only.

Lubetzky et al.²⁴ (n=20) conducted a randomized trial, with crossover on the effect of music compared to no music on REE. Metabolic measurements were obtained by indirect calorimetry which allowed for continuous measurements of oxygen consumption and carbon dioxide production. The authors reported that the REE was similar during the initial 10-min period of both randomized groups. Infants exposed to music had a significantly lower REE during the second and third 10 min periods than when they were not exposed to music.

Recorded Music Combined With Kangaroo Care

Kangaroo care is a method of holding an infant upright in mother-infant skin-to-skin contact. In a study of 30 infants less than 37 weeks' gestational age at birth, Lai et al.²² compared the influences of a no-music condition with those of a condition involving recorded lullabies during kangaroo care on maternal anxiety and preterm infants' responses, including HR, oxygen saturation, respiratory rate, and behavioral state. Mothers were allowed to choose the type of music from three options: western vocal, instrumental lullaby, or aboriginal Taiwanese lullaby. Infants in the intervention group had significantly more quiet sleep states and less crying.

Vocal Stimulation (Recorded and Live) With Auditory, Tactile, Visual, and Vestibular (ATVV) Stimulation

Six studies included vocal stimulation (recorded or live) as a component of an ATVV stimulation.²⁷⁻³² The ATVV intervention provides female human voice auditory stimulation, tactile stimuli through moderate touch stroking, visual stimuli in the form of eye-to-eye contact, and rocking as vestibular stimulation.³³ In one study, Whipple³⁴ evaluated the effects of parent training in music and multimodal ATVV stimulation. Table 2 includes a summary of the characteristics of these studies.

Table 2. Summary of Vocal Stimulation (Recorded and Live) With Auditory, Tactile, Visual, and Vestibular Stimulation Studies

None of the studies of ATVV stimulation reported the decibel levels of the auditory stimulation or described whether there were any accompanying instruments. The gestational ages at birth of infants enrolled in these studies ranged from 25 to 36 weeks. The sample size of each study varied from 20 to 54. The most frequently reported finding in the ATVV studies was that, in comparison

with the routine-care group, the intervention group demonstrated increased alert state or state of arousal both during the intervention and for 30 min after the intervention.^{27,31,32}

White-Traut, Nelson, Silvestri, Patel, and Kilgallon²⁷ (n=40) reported that, in comparison with infants in the routine-care group, those in the intervention group showed an increase in HR (149 bpm to 155.5 bpm, respectively) and a decrease in oxygen saturation (96.4% to 95.7%, respectively). These authors also noted an increased alert state during the intervention and for 30 minutes after the intervention.

In a subsequent study, White-Traut, Nelson, Silvestri, Cunningham, and Patel³¹ (n=54) found that any group exposed to a protocol that contained a tactile component demonstrated increased arousal, HR, and respiratory rate during the actual stimulation. Standley²⁸ (n=40) found that females receiving an ATVV intervention were discharged an average of 11.8 days earlier than those females in the routine-care group were discharged. There was no difference between days to discharge for males in the intervention and those for males in the control group. However, males and females in the intervention group exhibited a higher weight gain per day than did both genders in the control group.²⁵

White-Traut, Nelson, Silvestri, Vasan, Patel, and Cardenas³² (n=22) compared the effects of infant-directed talk via a live female voice paired with ATVV versus those receiving routine care. These investigators found that the experimental group's alert state during the intervention was higher than that of the control group. In addition, in comparison with infants in the control group, those in the experimental group demonstrated higher levels of five of eight feeding-readiness behaviors during the intervention. Despite the increase in feeding-readiness behaviors in the experimental group, the feeding volume and duration of feeding of this group were not significantly different from those of the control group.

Whipple³⁴ (n=20) evaluated the effects of parent training in music and ATVV multimodal stimulation on (a) parent-neonate interaction, (b) weight gain, and (c) length of NICU stay. Appropriate parent scores were not clearly defined in the publication; however, parent scores were reported as significantly higher for the experimental group. There were no significant differences for weight gain or length of stay. The effects of music on the preterm infants in this study are unclear because of numerous uncontrolled extraneous variables. Music listening was intermittent, and there was no description of the kind of music or of the noise level. In addition, parents were told of music benefits before the study, and parents in both the music and multimodal stimulation groups provided music.

Pacifier Activated Lullaby (PAL) Stimulation

Three studies consisted of evaluations of the effects of PAL stimulation.³⁵⁻³⁷ Table 3 includes a summary of these studies. The PAL uses lullabies as

contingent reinforcement for sucking, and is set so that a suck of predetermined strength activates the music.³⁶

Table 3. Summary of Pacifier-Activated Lullaby (PAL) Studies

Standley^{36,37} (n=12; n=32) and Cevasco and Grant³⁵ (post hoc analysis; n=62) investigated the effects of PAL on nonnutritive sucking, feeding rates, and weight gain. Standley³⁶ found that sucking rates were significantly greater in the experimental period with contingent music than at baseline. In her 2003 study, Standley found that there was no difference between the morning feeding rates of the experimental group and control group. The afternoon feeding rate was significantly higher for the experimental group, though significance was questionable. Additionally, the confounder of nurse feeding techniques was not addressed.³⁷ To evaluate the effects of PAL on weight gain, Cevasco and Grant³⁵ conducted a post hoc analysis. Results showed that the number of PAL trials completed (1 to 4) did not influence infant weight gain and that, although there was a trend toward greater weight gain with PAL use, individual variability within groups was greater than group differences

Research Involving Live Music and the Preterm Infant

Four studies utilized live music.³⁷⁻⁴¹ Table 4 includes a summary of these four live music studies.

Table 4. Summary of Live-Music Studies

Blumenfeld and Eisenfeld³⁹ (n=11) measured the effects of mothers' live singing on HR, respiratory rate, duration of feeding, and feeding volume. Arnon et al.³⁸ (n=31) examined effects of live-music versus recorded lullabies on physiologic measures, including HR, respiratory rate, oxygen saturation, and behavioral parameters. Kemper and Hamilton⁴¹ (n=8) studied the effects of live harp music on salivary cortisol (SC), heart rate variability (HRV), and motor activity in eight infants who were at least 34 weeks gestation (36.4 mean gestational age). Hodges and Wilson⁴⁰ (n=20) measured the effects of a 15-min live music therapy intervention on heart rate, oxygen saturation, level of motor activity, behavioral distress, and behavioral state levels.

Although Blumenfeld and Eisenfeld³⁹ found no significant results, Arnon et al.³⁸ reported that in the 30 minutes after the live-music intervention, HR was significantly lower (150 versus 127) and infants had deeper sleep states compared to the control period. Kemper and Hamilton⁴¹ reported a significant decrease in activity in the harp group during the 2 hours following the intervention compared to the other two groups. Hodges and Wilson⁴⁰ found that there were no significant effects associated with the music therapy intervention on HR, oxygen saturation, motor activity, or behavioral distress levels. During the music

condition, there was an increased mean percentage of time in the active sleep state and a decreased percentage of time in the drowsy state.

There are several possible reasons for the different findings among the studies by Blumenfeld and Eisenfeld,³⁹ Arnon et al.,³⁸ and Hodges and Wilson.⁴⁰ One involves the difference in sample size. Blumenfeld and Eisenfeld included 11 subjects, and only 20% of mothers who agreed to participate followed through with the study. Hodges and Wilson recruited 22 infants, with only 20 completing the study. Other possible explanations include the choice of music and other stimulation surrounding the intervention.

In the Arnon et al.³⁸ and Hodges and Wilson⁴⁰ studies, infants were exposed to lullabies sung by a female vocalist and included an accompanying instrument. Blumenfeld and Eisenfeld³⁹ allowed mothers to choose the type of music that they wanted to sing, and options varied from nursery rhymes to contemporary pop. Blumenfeld and Eisenfeld had no control over the tempo and volume of the music, positioning of the baby, or other procedures performed during the day, whereas Arnon et al. placed all infants in the supine position, controlled the decibel level of the music, imposed control over the environmental noise, and carried out all interventions one hour after completion of feeding. Hodges and Wilson allowed all infants to remain in the nurse-chosen position and controlled the decibel level and tempo of music.

Review Studies of Music Interventions With Preterm Infants

Standley⁴² published a meta-analysis of 10 studies of music therapy for preterm infants. These 10 studies were published from 1991 to 2000, with sample sizes ranging from 9 to 66 participants. Nine of the studies included recorded music, and only one study had live music as the intervention. All 10 studies included lullabies as the type of music that was used. The music intervention was compared with routine auditory stimulation in 5 studies and with white noise in one study. Two studies involved the evaluation of lullabies contingent on pacifier activation.

On the basis of findings from this meta-analysis, Standley⁴² recommended that music in the NICU should be non-alerting, with a constant volume and rhythm. She also recommended (a) that vocal music should be provided by a female or child, with a maximum of one accompanying instrument; (b) that volume level for music be in the low 70 dB range (never greater than 75 to 80 dB); (c) that music be provided in short intervals of 20 to 30 min throughout the day; and (d) that live singing be steady, constant, quiet, soothing, and infant directed. Music classified as a lullaby generally meets these criteria for music selection.³⁷

Hartling et al.⁴³ also published a systematic review of nine randomized controlled trials that were published from 1989 to 2006, with sample sizes ranging from 14 to 121 participants. Six studies included preterm infants and three included term

infants. Eight studies included recorded music, and only one study had live music. Six studies included lullabies, two included classical music, and one categorized the music as soothing. The music interventions were compared to a variety of other conditions including intrauterine sounds, routine, auditory stimulation and nursery rhymes metronomised to a real human heartbeat. Two studies included evaluation of pacifier activated lullabies as one condition.

Based on the review findings, Hartling et al.⁴³ suggested that although there is some evidence of benefits from the use of music with the neonatal population, additional research is required. The authors reported the two major methodological flaws with the reviewed studies to include (A) lack of clarity on randomization to groups, and (B) lack of double-blinding. The authors did concede that double-blinding in this situation may not always be possible. Small sample sizes were seen also as a limitation to the reviewed studies.

Summary

Evaluating studies about music, music interventions, and music therapy in the preterm infant was difficult because of the wide variations in music type, music delivery mode, music volume, music duration, other types of stimulation, and gestational ages of subjects. Of greatest concern were the wide range of decibel levels (35–80 dB), failure to report the scale of decibel measurement, and inconsistency in the means of music delivery. In several cases, infants wore earphones; in other studies, music was provided through speakers inside the isolette that were placed 3 to 20 inches from the infant's head. There was inconsistency in the duration and frequency of the music intervention that was provided, and no authors reported a rationale or justification for the selected duration. Reported results were often questionable because of poorly described data collection methods, lack of environmental description, failure to blind data collectors, and vaguely defined variables. A variety of behavioral and physiologic dependent variables were examined in these studies: auditory and visual function, motor and tactile/adaptive maturation, limb movement, maturation at discharge, stress behaviors, arousal state, weight gain, calorie intake, feeding rate, length of hospital stay, HR, BP, respiratory rate, oxygen saturation, and parent-infant interaction. The studies varied in sample size and characteristics, procedures for selection of study participants, design, and methods of data analysis. The most significant limitation of research involving music in the preterm infant consisted of the lack of a conceptual framework that adequately addressed the many characteristics that may have affected infants' responses to music, as well as addressing possible mechanisms by which music might affect the infant. Additional limitations included lack of information on morbidity levels of the infants during data collection sessions; failure to measure the actual decibel level of music at the infant's ear; poorly defined variables; and failure to measure possible extraneous variables such as ambient noise, number of visitors/staff in nursery, and other stimulation received by the infant. Another potential confounder was the lack of discussion about the timing of the intervention or data

collection. Few reports indicated consistency in the time of day at which data were collected. Sample sizes were often small and acknowledged as a limitation; however, very few authors reported a power analysis and/or why a specific sample size was chosen.

Despite the limitations of the studies, the findings of many studies suggest that music interventions may have positive effects on preterm infants in the NICU including increased oxygen saturation levels, reduced heart rates, reduced arousal and behavioral stress responses, increased levels of quiet alert or quiet sleep states, improved parent-infant interaction, improved weight gain, and reduced length of hospitalization.

The inconsistencies noted in this review suggest numerous directions for future research. Future studies should be based on clear conceptual models that specify the characteristics of the infant, setting, and intervention itself that might influence the infants' responses to the music intervention, and propose mechanisms by which music might influence infant responses. Characteristics of the infant that might affect response to the intervention and that should be considered include gender, gestational age, morbidity status, behavioral state and hunger level at the time the music is administered, and exposure to other types of stimulation. Characteristics of the setting that should be considered include lighting level, ambient noise level, temperature, number of visitors and staff in the unit when the intervention is provided, and whether the NICU is a "developmentally friendly" environment. Characteristics of the intervention that should be considered include type of music (e.g. live versus recorded, sedating versus stimulating, maternal voice versus other voice), decibel level, whether it is provided contingent on infant cues), as well as the "dose" of the intervention, including frequency, duration, and timing.

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